Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 23 Issue 1 Version 1.0 Year 2023
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Fibre Polymer and its use in Construction Industry

By Abed Alhakim Ibrahim Shehadeh Khaleel, Mohammad Amin Yousef Ibrahim Abu Shinnar & Qusai Zakaria M.Abuhadba-Abushunnar

Research Summary- Concrete structures can be strengthened by using repair, restoration, and development. Fiber-reinforced polymers, where the use these materials has increased in recent years because of the many advantages of these compounds compared to traditional materials such as steel. Among the most important of these features: are a high strength-to-weight ratio, high energy absorption and resistance excellent abrasion and high tensile strength. By taking the following two variables:

1- The number of layers of carbon fiber.
2- Rotate the edges of the samples.

The analytical results showed good agreement with the experimental results, and the analytical model showed the importance of the fibers.

Rounded cross-section edges and the number of carbon fiber layers increase the bearing capacity of the concrete columns, also rounding the edges of the column prevented the concentration of stresses and contributed to the increase of the enclosing area.

GJRE-E Classification: LCC: TA1-TA2040

FIBREPOLYMERANDITSUSEINCONSTRUCTIONINDUSTRY

Strictly as per the compliance and regulations of:

Fibre Polymer and its use in Construction Industry

Abed Alhakim Ibrahim Shehadeh Khaleel [α], Mohammad Amin Yousef Ibrahim Abu Shinnar [σ] & Qusai Zakaria M.Abuhadba-Abushunnar [ρ]

Research Summary- Concrete structures can be strengthened by using repair, restoration, and development. Fiber-reinforced polymers, where the use these materials has increased in recent years because of the many advantages of these compounds compared to traditional materials such as steel. Among the most important of these features: are a high strength-to-weight ratio, high energy absorption and resistance excellent abrasion and high tensile strength. By taking the following two variables:

1- The number of layers of carbon fiber.
2- Rotate the edges of the samples.

The analytical results showed good agreement with the experimental results, and the analytical model showed the importance of the fibers.

Rounded cross-section edges and the number of carbon fiber layers increase the bearing capacity of the concrete columns, also rounding the edges of the column prevented the concentration of stresses and contributed to the increase of the enclosing area.

I. Introduction

The cracking and fragmentation that occurs in concrete columns are often accompanied by steel submission.

Reinforcement and its inability to bear, recently the most common method to strengthen the structural elements is the use of steel reinforcement and the application of steel shirts on concrete columns. The use of these shirts provided the horizontal encirclement of the concrete and showed apparent effectiveness in increasing the bearing capacity of the concrete columns. However, the primary defects using of steel shirts are that their corrosion resistance is low and their cost is high in addition to their heavy weight.

Fiber Reinforced Polymers (FRP) appear to be an alternative and practical choice, due to their high strength and hardness relative to their weight, and their corrosion resistance. Therefore, using these materials has become the subject and goal of many studies in recent years due to its many advantages.

II. Research Objective

The research aims to introduce polymers, their types, and their structural uses.

Author α: e-mail: hakeemspy@gmail.com

III. Research Importance

The importance of the research comes from the need to develop construction building materials and use materials with low cost and high durability in building and construction.

IV. Research Problem

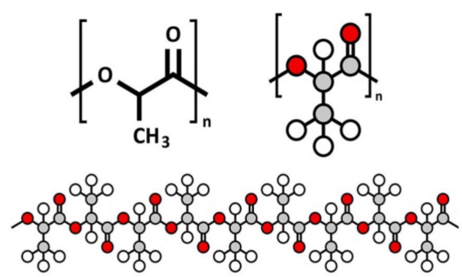
The research problem comes from the research question, which is:

What are polymers and reinforced polymer fibers, and how are they used?

V. Search Terms

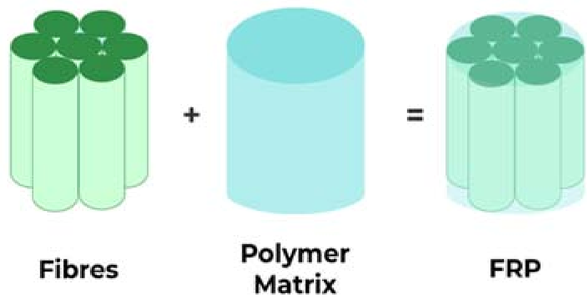
a) Polymers

Polymers are materials made of long, repeating chains of molecules. These materials have unique properties, depending on the type and how they are bonded.



b) Fiber Reinforced Polymer (FRP)

It is a composite material made of a polymeric network reinforced with fibers; which is usually made of glass, Carbon, aramid, or basalt. These fibers are distinguished in their use in construction fields and have distinctive properties with concrete as they produce potent compounds that increase the hardness and resistance of concrete when adding it to it and also enhance its dynamic properties.



VI. Fiberglass Polymer (FRP) Features

a) Lightweight

FRP has a density of approximately 14-21 kN/m3, which is only about one-sixth to one-fourth that of steel and even lighter than aluminum. When used in large-span structures, FRP can significantly reduce the weight of the structure. For instance, the entire carbon fiber roof of the Job Theater weighs only 80 tons and can be erected through lifting. With a roof diameter of around 47 meters, the average weight per square meter is approximately 46 kg, which is comparable to that of a 6 mm thick steel plate. This remarkable weight reduction effect enables the roof to support the weight of surrounding structural glazing, creating a stunning spatial effect.

b) High Strength

Natural materials often contain defects in their crystal structure. Finer materials tend to have fewer defects and higher strength. The strength of carbon and glass fibers can be 10-20 times that of steel. Due to the strength difference between fibers and matrix, the strength-to-weight ratio of FRP materials is typically more than four times that of steel, enabling FRP structures to have larger spans than traditional structures. For instance, researchers have used CFRP cables to construct the 10,000-meter-long Gibraltar Bridge, which demonstrates the remarkable strength of FRP materials.

c) Easy to Shape

The production of FRP involves several methods, including extrusion, rolling, hand laying, and injection molding. While it may not be feasible to manufacture FRP products on a large scale, sheets of almost any shape can be produced to create non-linear architectural forms.

d) Easy to Disassemble and Assemble

e) Modulus of Elasticity

The modulus of elasticity of FRP is equivalent to that of concrete and wood. Compared with its high strength, structural design is often controlled by deformation. Deformation can be controlled by a reasonable selection of structural shape, combination with other materials, and prestressing.

f) Linear Expansion Coefficient

Much smaller than steel, aluminum, and other metallic materials. On the one hand, it will not cause apparent temperature stress when applied to very tall structures, conducive to structural design; On the one hand, it has a better thermal insulation effect, and an additional insulation layer is no longer needed for the building to save building space.

g) Fire Resistance

The resin will soften at high temperatures and lead to decreased mechanical properties. FRP + surface fire-retardant treatment method can improve the resin's fire-retardant performance. The fireproof effect of well-cured FRP can be equivalent to that of concrete.

Economical: The price of FRP material is higher than that of steel. However, the overall cost is competitive, due to their lightweight, high strength, corrosion resistance, and low maintenance requirements.

VII. Disadvantages of Polymer Fibers

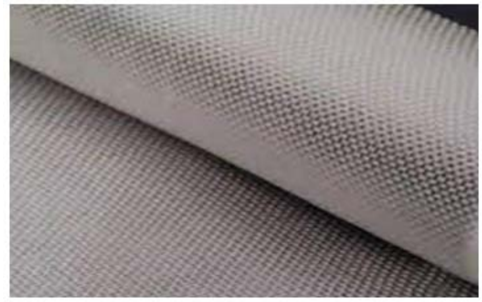
The negatives can be summarized as follows:

1- The high cost of materials despite the increased usage in recent years.
2- Low deformation at collapse, which requires suitable design methods.
3- Low lateral bearing capacity due to poor mechanical properties, especially For FRP not Aramid.
4- Expansion due to moisture absorption, especially for FRP from not Aramid (Aramid FRP).
5- Rapid and severe loss of bonding, resistance, and hardness at high and extreme temperatures the thing in the event of a fire.

Global Journal of Researches in Engineering (E) Volume XXIII Issue I Version I Year 2023

VIII. Types of Polymer Fibers

a) Glass Fiber Reinforced Polymers (GFRP)



Glass fiber is mainly made by mixing silica sand, limestone, folic acid, and other minor ingredients. The mixture is heated until it melts at about 1260°C.

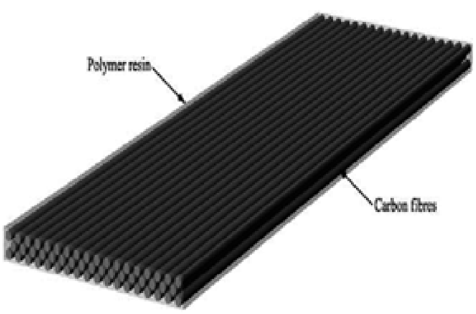
The molten glass is then allowed to flow through the tiny holes in a platinum plate, forming threads. The glass filaments are cooled and bundled. The fibers are pulled to increase their directional strength. The fibers are then spun into various shapes for use in vehicles.

Properties:

Based on aluminum-borosilicate lime composition, glass fibers are the dominant reinforcement of reinforced polymer composites due to their excellent electrical insulating properties, low susceptibility to moisture, and high mechanical properties.

Glass is generally a good impact-resistant fiber but weighs more than Carbon or aramid. Fiberglass has excellent properties equal to or better than iron in specific applications.

b) Carbon Fiber Reinforced Polymers (CFRP)

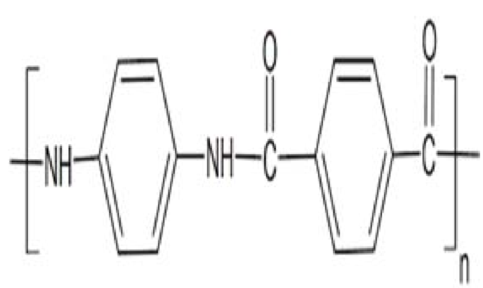


Carbon fiber has a high modulus of elasticity, 200-800 GPa. The final extension is 0.3 - 2.5%, where lower extension corresponds to higher hardness and vice versa.

Properties:

Carbon fiber does not absorb water and it resists to many chemical solutions. Carbon fiber has excellent bearing stresses, does not wear out.

c) Aramid Fiber Reinforced Polymers (AFRP)



Aramid is the short component for aromatic polyamide. There are many brands of aramid fiber, but the well-known one is Kevlar, and the others are Twaron, Technora, and SVM.

The fiber size is 70 - 200 GPa with a final elongation of 1.5 - 5%, depending on the quality. Aramid has high breaking energy and is therefore used for bulletproof helmets and clothing.

Global Journal of Researches in Engineering (E) Volume XXIII Issue I Version I Year 2023

Properties:

Aramid fibers are sensitive to high temperatures, humidity, and UV rays and are, therefore, not widely used in civil engineering applications. Finally, aramid fibers have problems relaxing and corroding under stress.

IX. Applications and Structural uses of FRP Fiber-reinforced Polymers

- Prestressed concrete applications that require high resistance to corrosion and electromagnetic transparency often use Carbon FRPs, also known as CFRP.
- In offshore platforms, underwater piping, and other structural parts, CFRP composites are commonly used. Additionally, FRP reduces fire hazards.
- Carbon fiber reinforced polymers are used to manufacture underwater pipes that can reach great depths due to their lower density, which provides a significant increase in buoyancy compared to steel.
- To reduce weight and resist wear, stairs and hallways can be constructed using FRPs.
- High-performance hybrid architectures often incorporate FRPs.
- To increase durability, FRP bars are used as internal reinforcement for concrete structures.
- Various structures made from concrete, masonry, timber, and even metal can be reinforced with FRP bars, sheets, and strips.
- FRPs are utilized in seismic rehabilitation and restoration projects.
- Fiber-reinforced polymers are employed in the construction of special structures that require electrical neutrality.
- AFRP's high energy absorption capacity makes it suitable for reinforcing engineering structures that are subjected to dynamic loads.

X. Reinforcing Concrete Beams using Fiber-reinforced Polymer

What does it mean to strengthen concrete beams with fiber-reinforced polymer?

Reinforcing a reinforced concrete beam with fiber reinforced polymer involves installing rods made of this material close to the surface of the beam. There are several factors that can reduce the maximum load capacity of concrete structures, including corrosion of steel in aggressive environments, errors in design calculations, and poor mix design. Demolishing and rebuilding dilapidated structures is also not cost-effective.

As such, it is of paramount importance to enhance and fortify the peak capacity of structures or restore their strength in cases of degradation. Numerous methods and techniques have been employed to improve reinforced concrete elements, including the use of externally bonded panels consisting of steel panels and fiber-reinforced polymer layers. Among these methods is FRP near-surface composite technology, which has proven effective in enhancing reinforced concrete elements.

Procedures of the Near Surface Fixed Fiber Reinforced Polymer Technology:

1. Cut grooves on the crossbar cover along the tension side.
2. Use the brush and compressed air to remove debris in the grooves.
3. The last epoxy or plaster cement is inserted into the two-thirds ratio of the groove as a binder.
4. The fiber reinforced polymer tape is pushed into the binder materials until it is surrounded by the bonding agent.
5. Subsequently, the remaining portion of the groove is filled with epoxy putty.

In this process, the steel reinforcement must be prevented from cutting or the element will lose all capacity. Therefore, the covering of the reinforced concrete part must be at least 20 mm thick to be strengthen in this way.

XI. Studies on Columns Surrounded by Carbon-reinforced Polymer Fibers

Several theoretical and experimental studies have been conducted to calculate the bearing capacity of encircled concrete columns with carbon fibers and most of the studies considered the effect of covering the circular columns, noting that. Square or rectangular cross-sections are used more in our practical reality, so the focus has been placed this research to conduct an analytical study on a model of square-shaped and loaded column pivotally.

To determine the bearing capacity of the columns, it is necessary to create an experimental model that forecasts how the columns will behave.

- A predictive experimental model must be established to ascertain the bearing capacity of the columns.
- The columns' bearing capacity can be determined by developing an experimental model that predicts their behavior.
- By applying both transverse reinforcement and carbon fibers, the columns were formed with combined banding.

Since in rectangular columns, the lateral pressure is generally different in both directions. The behavior of concrete is described by the stress-deformation curves E and H. Linear and flexible curves up to 30% of the maximum resistance of concrete to pressure, and this increases. The curve is gradually above this point until (70-90%) of the ultimate resistance to stress.

Immediately after the ultimate value, the stress-deformation curve descends; this part of the curve is determined ductility of concrete. After the slope of the curve, refraction occurs at the maximum deformation (10) E$\boldsymbol{cu}$ the value of maximum deformation decreases with increasing compressive strength of concrete; Deformation value depends on the bearish part is mainly based on experiments used to obtain a curve Stress-deformation. Numerous mathematical models have been presented to characterize a curve Stress-deformation of concrete includes several cases, including the study of the effect of banding with carbon fibers on unreinforced concrete models as the model provided by Lam and Teng. The method was approved by the American code (R.ACI440-08), and other researchers have conducted studies related to this topic. For instance, Kent and Park presented a model to characterize the stress-deformation curve equation for concrete, which can be used to investigate the effect of accidental delivery on circular sections. Other models have been developed for rectangular sections. Additionally, Mander et al. conducted a study on the role of encircling methods in enhancing the influence of longitudinal and transverse reinforcement for both circular and rectangular sections.

XII. The Future of Polymers

Scientists are actively exploring and testing various novel types of polymers to improve drug development and enhance everyday products. One promising area of research involves the use of carbon polymers in the automotive industry, which is currently being developed and promoted.

“Carbon fiber reinforced polymer composites – also called carbon fiber laminates – are the next generation materials for making cars lighter, more fuel efficient, and safer. Carbon sheets are solid and rigid due to their woven layers of pure carbon fibers combined with a rigid plastic composite,” according to a study by two researchers, Nikhil Gupta and Steven Zeltman, in the Mechanics of Composite Materials Lab, Department of Mechanical and Aerospace Engineering, NYU Tandon.

Polymer is also used in hologram enhancement. Scientists at the University of Pennsylvania created a hologram on a flexible polymer material embedded in gold nanoparticles, according to a study published online in early 2017 in the journal NanoLetters. The new hologram device can take several pictures instead of just one.

Ritesh Aggarwal, a researcher and professor of materials science and engineering at the University of Pennsylvania, asks a question and says: “Can we encode a lot of information in a 3D image?" "It's an important piece of work," he adds, "because it's the first time someone has shown you can record multiple 3D images, and with stretch polymers, you can change the whole idea.

Factors affecting the design of FRP:

XIII. There are Several Factors Affecting the Design of FRP, Namely

- The spacing between grooves.
- The thickness of concrete between the FRP bars and steel.
- Concrete compressive strength.
- The axial stiffness of FRP rods.
- Perimeter reinforcement using FRP rods.
- The ratio of FRP to steel reinforcement.
- The distance between reinforcing edge and grooves.
- And types of failures in reinforced concrete beams.

XIV. Conclusions

In the following research, we reached many conclusions, including:

- The need to use polymer fibers of various types in construction and construction.
- Polymer fibers have several advantages and benefits, including:
- Carbon fiber fabric has lightweight, as its density is not more than ¼ of steel's.
- The strength of the carbon fiber fabric is so high that 1mm of this fabric is sufficient to replace the reinforcement without any increase in the weight or cross-section of the supporting element.
- The carbon fiber fabric is very single-curved as it can be applied to elements in any geometric shape and a narrow space.
- Applying unidirectional carbon fiber fabric is straightforward and does not require substantial mechanical devices or complex equipment.
- The applicability of the unidirectional carbon fiber fabric is very high, as it can be applied as reinforcement on concrete, wooden, and masonry structures.
- And we find that the polymer fibers have several disadvantages, including:

a) Double Long-term Temperature Resistance

In general, FRP is not suitable for prolonged use at high temperatures. The strength of general-purpose polyester FRP significantly decreases below 50 degrees Celsius and is typically used only below 100 degrees Celsius. Similarly, the strength of general-purpose epoxy FRP reduces above 60 degrees Celsius. However, it is feasible to select a high-temperature resistant resin that can enable long-term operation at temperatures ranging from 200 to 300°C.

b) Aging Phenomenon

Aging is a common defect of plastics, and FRP is no exception. It is easy to cause performance deterioration under the influence of ultraviolet rays, sand, rain, snow, and chemical and mechanical stress.

c) Low Shear Strength

The interlaminar shear strength of the resin is quite low, which can be improved by selecting an appropriate process, using a coupling agent, and most importantly, avoiding shearing between layers during product design. Enhancing the adhesion between layers is crucial for improving the overall strength of the product.

References Références Referencias

1. C. Ershad "Behaviour of Fibre Reinforced Polymer Confined Reinforced Concrete Columns under Fire Condition" Kingston, Ontario, Canada, 2009.
2. ACI Committee 440. Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures; ACI 440.2R-08 American Concrete Institute: Farmington Hills, MI, USA, 2008.
3. H. E., A Study of Combined Bending and Axial Load in Reinforced Concrete Members, Illinois: University of Illinois Engineering Experiment Station, 1951.
4. P. S., "Review of Stress-Strain Relationships for Concrete," ACI Journal Proceddings, vol. 67, no. 3, pp. 243-248, 1970.
5. Lam, L.; Teng, J.G. Design-Oriented Stress-Strain Model for FRP-confined Concrete in Rectangular Columns. J. Reinf. Plast. Compos. 2003, 22, 1149–1186.
6. P. R. Kent DC, "Flexural Members with Confined Concrete," J Struct EngASCE, vol. ST7, no. 97, 1971.
7. Mander, J. B.; Priestley, M.J.N.; Park, R. Seismic design of bridge piers; Research Report No. 84–2; University of Canterbury: Christchurch, New Zealand, 1984.
8. ANSYS. Manuals, 2015.
9. M. W. Hadi, "Axial and flexural performance of square RC columns wrapped with CFRP under eccentric loading," Journal of Composites for Construction, vol. 16, no. 6, pp. 640-649, 2012.
10. https://www.researchgate.net/publication/.
11. Choi. H. T.; West, J. S.; Soudki, K. A., 2008, Analysis of the flexural behavior of partially bonded FRP strengthened concrete beams' journal of composites for construction, /July/August., P375-286.
12. Taljsten, B., 2003, FRP strengthening of existing concrete structures design guidelines, lulea university printing office: lulea, sweden,.
13. Dussek I. J., 1974, Strengthening of bridge beams and similar structures by means of epoxy resin bonded external reinforcement, Transport research record, National Research Council, No. 785, 1974, pp21-24.
14. https://theconstructor.org/concrete/using-nsm-frp-rc c-beam-strengthening/13238/.